1. **R3:** Framing: there is also framing in IP and TCP;
   link access;
   reliable delivery: there is also reliable delivery in TCP;
   flow control: there is also flow control in TCP;
   error detection: there is also error detection in IP and TCP;
   error correction;
   full duplex: TCP is also full duplex.

**R6** : After the 5th collision, the adapter chooses from {0, 1, 2,..., 31}. The probability that it chooses 4 is 1/32. It waits 204.8 microseconds.

**R9**: 2^48 MAC addresses; 2^32 IPv4 addresses; 2^ 128 IPv6 addresses.

**R11**. An ARP query is sent in a broadcast frame because the querying host does not which adapter address corresponds to the IP address in question. For the response, the sending node knows the adapter address to which the response should be sent, so there is no need to send a broadcast frame (which would have to be processed by all the other nodes on the LAN.

## Problem 8

a)

$$\begin{aligned} E(p) &= Np(1-p)^{N-1} \\ E'(p) &= N(1-p)^{N-1} - Np(N-1)(1-p)^{N-2} \\ &= N(1-p)^{N-2}((1-p) - p(N-1)) \end{aligned}$$

$$E'(p) = 0 \Rightarrow p^* = \frac{1}{N}$$

b)

$$E(p^*) = N\frac{1}{N}(1-\frac{1}{N})^{N-1} = (1-\frac{1}{N})^{N-1} = \frac{(1-\frac{1}{N})^N}{1-\frac{1}{N}}$$

$$\lim_{N\to\infty}(1-\frac{1}{N}) = 1 \qquad \lim_{N\to\infty}(1-\frac{1}{N})^N = \frac{1}{e}$$

Thus

$$\lim_{N\to\infty} E(p^*) = \frac{1}{e}$$

## Problem 9

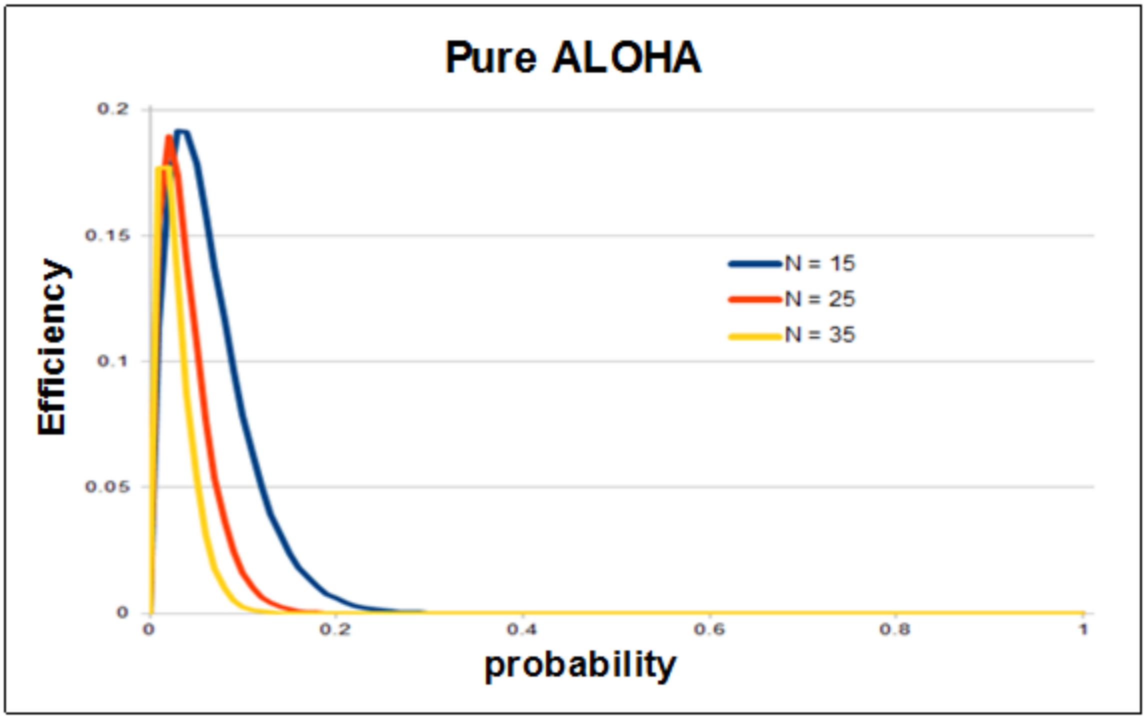
$$E(p) = Np(1-p)^{2(N-1)}$$
$$E'(p) = N(1-p)^{2(N-2)} - Np2(N-1)(1-p)^{2(N-3)}$$
$$= N(1-p)^{2(N-3)}((1-p) - p2(N-1))$$

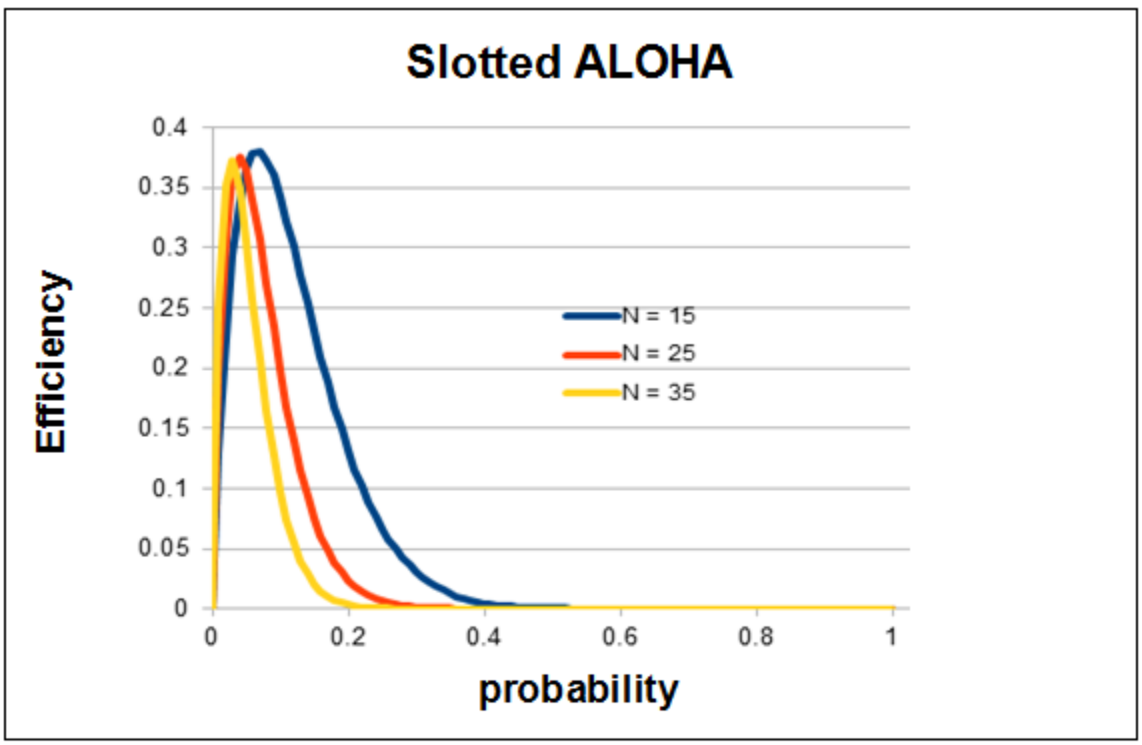
$$E'(p) = 0 \Rightarrow p^* = \frac{1}{2N-1}$$

$$E(p^*) = \frac{N}{2N-1}(1-\frac{1}{2N-1})^{2(N-1)}$$

$$\lim_{N\to\infty} E(p^*) = \frac{1}{2}\cdot\frac{1}{e} = \frac{1}{2e}$$

## Problem 12


Pure ALOHA
Efficiency
probability
N = 15
N = 25
N = 35
0.2
0.15
0.1
0.05
0
0
0.2
0.4
0.6
0.8
1


Slotted ALOHA
Efficiency
probability
N = 15
N = 25
N = 35
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.2
0.4
0.6
0.8
1

## Problem 13

The length of a polling round is

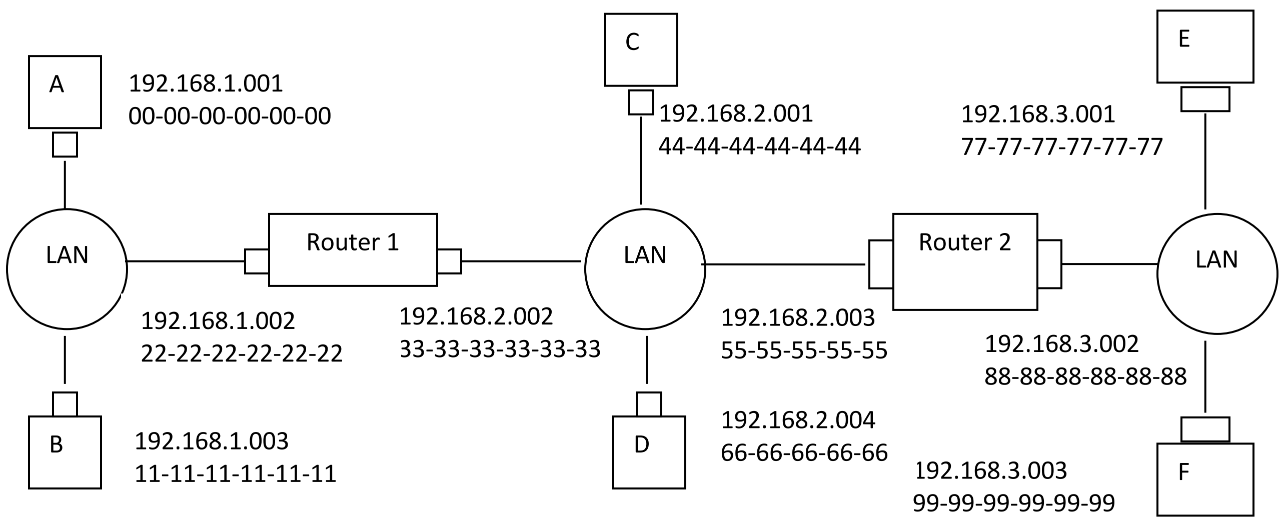
$$N(Q/R+d_{poll}).$$

The number of bits transmitted in a polling round is $NQ$. The maximum throughput therefore is

$$\frac{NQ}{N(Q/R+d_{poll})}=\frac{R}{1+\frac{d_{poll}R}{Q}}$$

## Problem 14

a), b) See figure below.

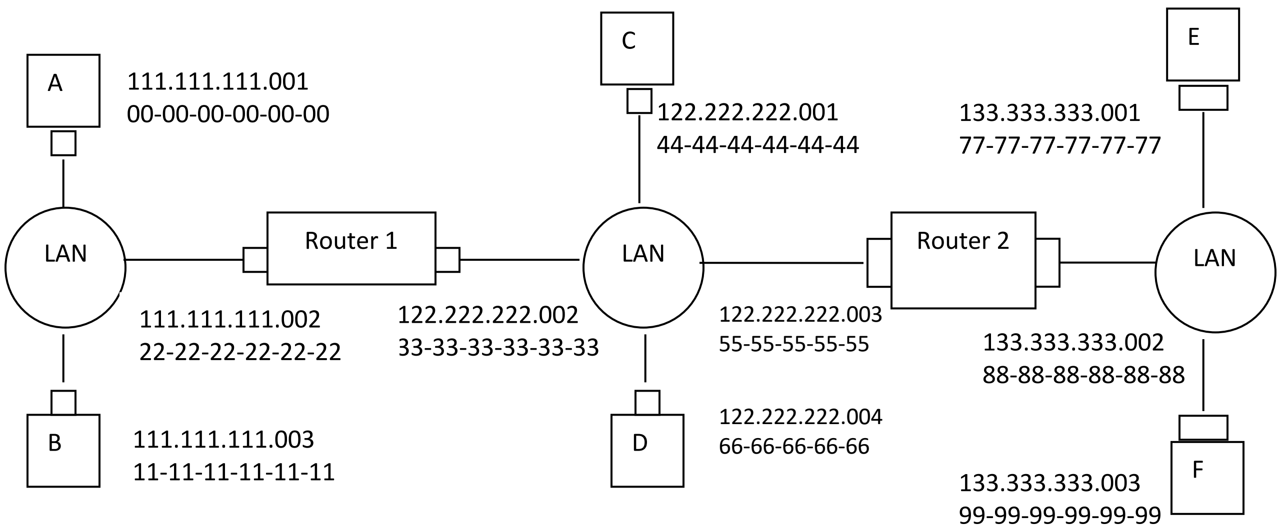



c)

1. Forwarding table in E determines that the datagram should be routed to interface 192.168.3.002.
2. The adapter in E creates and Ethernet packet with Ethernet destination address 88-88-88-88-88-88.
3. Router 2 receives the packet and extracts the datagram. The forwarding table in this router indicates that the datagram is to be routed to 198.162.2.002.
4. Router 2 then sends the Ethernet packet with the destination address of 33-33-33-33-33-33 and source address of 55-55-55-55-55-55 via its interface with IP address of 198.162.2.003.
5. The process continues until the packet has reached Host B.

a) ARP in E must now determine the MAC address of 198.162.3.002. Host E sends out an ARP query packet within a broadcast Ethernet frame. Router 2 receives the query packet and sends to Host E an ARP response packet. This ARP response packet is carried by an Ethernet frame with Ethernet destination address 77-77-77-77-77-77.

## Problem 21




i) from A to left router: Source MAC address: 00-00-00-00-00-00
Destination MAC address: 22-22-22-22-22-22
Source IP: 111.111.111.001
Destination IP: 133.333.333.003

ii) from the left router to the right router: Source MAC address: 33-33-33-33-33-33
Destination MAC address: 55-55-55-55-55-55
Source IP: 111.111.111.001
Destination IP: 133.333.333.003

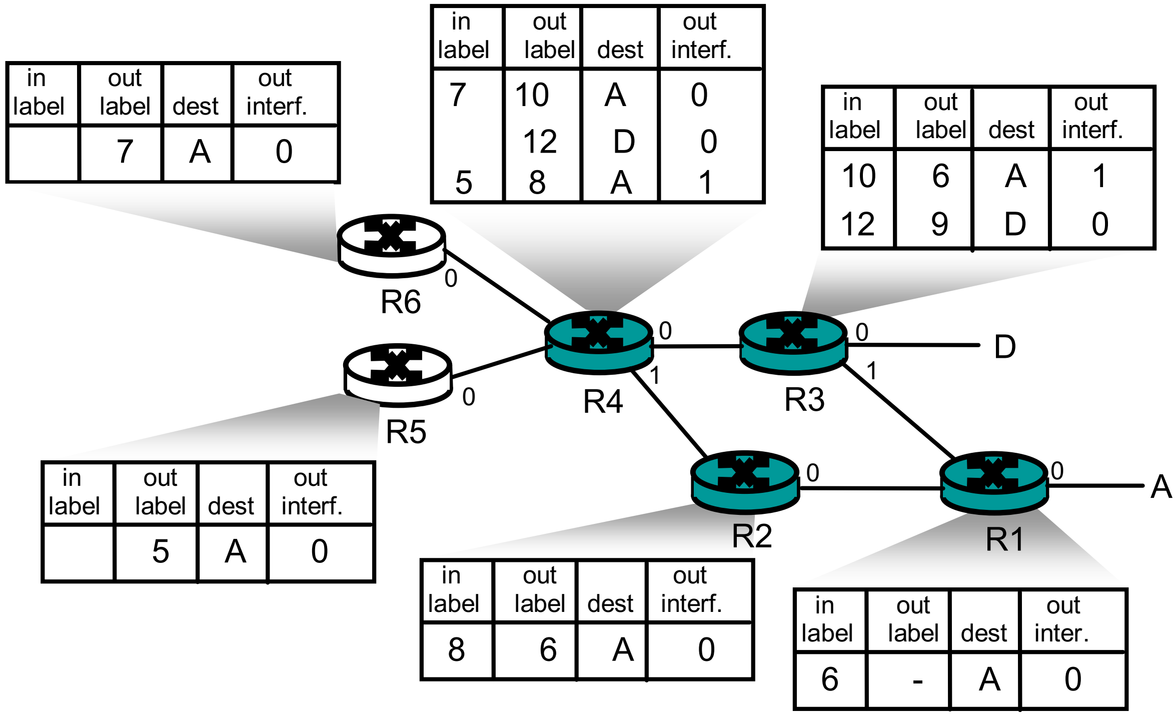
iii) from the right router to F: Source MAC address: 88-88-88-88-88-88
Destination MAC address: 99-99-99-99-99-99
Source IP: 111.111.111.001
Destination IP: 133.333.333.003

## Problem 22

i) from A to switch: Source MAC address: 00-00-00-00-00-00
Destination MAC address: 55-55-55-55-55-55
Source IP: 111.111.111.001
Destination IP: 133.333.333.003
ii) from switch to right router: Source MAC address: 00-00-00-00-00-00
Destination MAC address: 55-55-55-55-55-55
Source IP: 111.111.111.001
Destination IP: 133.333.333.003

iii) from right router to F: Source MAC address: 88-88-88-88-88-88
Destination MAC address: 99-99-99-99-99-99
Source IP: 111.111.111.001
Destination IP: 133.333.333.003

## Problem 29




**Problem 33**

a) Both email and video application uses the fourth rack for 0.1 percent of the time.

b) Probability that both applications need fourth rack is $0.001*0.001 = 10^{-6}$.

c) Suppose the first three racks are for video, the next rack is a shared rack for both video and email, and the next three racks are for email. Let's assume that the fourth rack has all the data and software needed for both the email and video applications. With the topology of Figure 5.31, both applications will have enough intra-bandwidth as long as both are not simultaneously using the fourth rack. From part b, both are using the fourth rack for no more than .00001 % of time, which is within the .0001% requirement.